5/pr/h JC12 Rec'd PCT/PTC 28 SEP 2005 10/550918

WORKTOOL

This invention relates to worktools and, in particular, rotating worktools, such as sanders and polishing machines, that engage with a surface.

Known orbital and random-orbital worktools, such as sanders, functioned by driving an abrasive surface in a circular path about a principal drive shaft. A surface may be of fixed orientation or may be free to rotate about an eccentric axis, according to whether the resulting motion is required to be orbital or random-orbital respectively. Such worktools typically suffer from vibration. Vibration in such systems has two distinct components, dynamic (which results from unbalanced centripetal acceleration) and frictional (which results from the translating frictional forces between the working surface of the tool and the work piece).

Dynamic imbalance can normally be corrected by distributing counter weights at particular axial, radial and phase positions on the drive axis of the work tool. However, this approach relies on the working surface of the tool, such as the sanding platen and any attached replacement component, being of constant mass. This means that changing the platen or replacing the working material can often cause unwanted vibration.

Vibration experienced in use also often arises from translating frictional forces between the abrasive surface acting so as to make the eccentric drive axis the centre of rotation. In the worst case, these vibrations can be of an amplitude equal to the shaft eccentricity, in the case that the principal drive shaft orbits the stationary eccentric shaft.

Frictional vibration increases with increasing contact force, resulting in a reduction of sanding efficiency that tends to zero as the amplitude of vibration tends to the eccentricity of the drive axis. A common misconception is that, by increasing the contact force, an increase in the material removal rate can be achieved. As such, counter-intuitive system behaviour in prior art solutions often results in poor sanding efficiency and high levels of vibration.

The present invention aims to reduce markedly vibration arising from translating frictional forces, by ensuring that such forces are reacted within a system of sanding surfaces, thereby increasing the sanding efficiency and the rate of material removal that can be achieved.

According to the present invention, there is provided a work tool comprising: a principal drive shaft with a sun gear attached thereto; at least two planetary gears distributed about the circumference of the sun gear at substantially equal angular separation; and a carriage for constraining the planetary gears such that they maintain their angular separation about the axis of the principal drive shaft, wherein each planetary

gear has an eccentric axis in addition to its rotational axis constrained by the carriage, such that each planetary gear can drive, in use, a platen around the respective eccentric axis.

The phase difference between the rotation of the eccentric axis of any two adjacent planetary gears about the respective rotation of axis is $2\pi/n$ radians, wherein n equals the number of planetary gears. n is preferably greater than or equal to 3. This relationship ensures that the centre of mass of the combined system does not depart from the principal axis of rotation.

In addition to the net linear frictional forces, the frictional force from each of the platens will produce a moment about the centre of the tool (centre of the sun gear). Furthermore, as the planetary gear rotates, the direction and position of the force changes, so the magnitude of the resulting moment will change. If these forces were unopposed, then the resulting varying moment would be transmitted to the user, as a torsional vibration. In order to preserve the dynamic balance of the system and to ensure that this component is cancelled in addition to the dynamic and linear friction forces, it is advantageous to define not only the magnitude of the eccentricity phase relationship between adjacent platens but also the relative direction of that phase relationship.

It is preferable that the rotation of the eccentric axis of a first planetary gear about its associated rotational axis has a phase difference in a clockwise direction of $2\pi/N$ relative to the rotation of the eccentric axis of a second planetary gear about its associated rotational axis, the second planetary gear being adjacent the first planetary gear in a clockwise direction.

According to a second aspect of the present invention, there is provided a worktool comprising: a principal drive shaft with a sun gear attached thereto; n planetary gears distributed about the circumference of the sun gear at substantially equal angular separation; and a carriage for constraining the planetary gears such that they maintain their angular separation about the axis of the principal drive shaft; wherein each planetary gear has an eccentric axis in addition to its rotational axis constrained by the carriage, such that each planetary gear can drive, in use, a platen around the respective eccentric axis, and wherein the rotation of the eccentric axis of a first planetary gear about its associated rotational axis has a phase difference in a clockwise direction of $2\pi/n$ relative to the rotation of the eccentric axis of a second planetary gear about its associated rotational axis, the second planetary gear being adjacent to the first planetary gear in a clockwise direction.

With the present invention, since the translating frictional forces are mutually reacted, vibration transmitted to the user is, in principle, decoupled from the applied

contact force. Similarly, sanding efficiency is not unduly compromised by increasing contact force, permitting higher rates of material removal. Such a feature of the present invention complements user initiation, unlike the prior art systems described above.

Furthermore, the arrangement of sanding elements is dynamically balanced, removing the need for the system of counter weights, in conventional sanders. The sanding platens and abrasive surfaces can also be replaced without unduly compromising the dynamic balance. The present invention can be configured to be operable in a number of modes, optimising the motion for a given sanding operation or spatial constraint.

The platens may be freely rotating or partially constrained from rotating with respect to the carriage, thereby fixing the orientation of the platens with respect to one another. Partially constraining the platens in this way permits the use of tessellating platen configurations.

The worktool may be a sander or a polisher. The principal drive shaft may be connected, optionally through an additional gear mechanism, to an electric motor.

Examples of the present invention will now be described with reference to the accompanying drawings, in which:

Figures 1 and 2 are isometric and plan views of a worktool according to the present invention;

Figure 3 is a plan view of a device according to the present invention, with an additional gear shown;

Figure 4 is a plan view showing alternative configurations of the platen only; and

Figure 5 shows the phase relationship between the rotation of the eccentric axis in a preferred example of the present invention.

Referring to Figures 1 and 2, the worktool includes a principal drive shaft 1 and a carriage 4 to which a sun gear 2 is attached. The worktool is typically a sander or polisher. A number of planetary gears 3 are distributed about the circumference of the sun gear 2 at equal angular separations. The planetary gears 3 are constrained by the carriage 4, locating the centres and maintaining the angular separation about the principal axis of the drive shaft 1. Each planetary gear 3 has an eccentric axis 5, in addition to the centre of rotation constrained by the carriage 4, driving a freely rotated or partially rotationally constrained platen 6.

If the platens are partially constrained from rotating, then alternative tessellating platen configurations are possible. Some examples of such configurations are shown in Figure 4 in which each of the platens 8 or 9 can be attached to a respective eccentric axis 5, instead of the circular platen 6 shown in Figure 1. Alternatively, in an embodiment that

employs four planetary gears 3, a rectangular platen 10 can be attached to each of the respective eccentric axis 5.

When free to rotate, the carriage 4 will be driven by a net torque between the sanding surfaces and the workpiece (not shown) causing the sanding centres to describe a distorted epicycloid where the number of rotations of the respective planetary gear is not purely a function of the sun/planetary gear ratio. This is a random motion most suited to finishing applications.

If the carriage 4 is prevented from rotating, preferably with a user engaged lock, the platens 6 will orbit a fixed centre, with no bulk rotation of the combined system. This constitutes a mode of operation suitable for sanding an inside corner that would be inaccessible by an equivalent single sanding platen of an area equal to the sum of the platen areas.

Figure 3 shows an optional additional gear 7 including inwardly facing teeth (not shown) which engage with each of the planetary gears. The gear 7 is concentric with the principal drive axis 1. When this additional gear 7 is free to rotate, the above modes are accessible. However, when prevented from rotating, again preferably with a user engaged lock, the platen centres will be driven in a strictly epicyclic motion. This results in higher surface to surface speeds and a corresponding increase in the rate of material removal.

Figure 5 shows a simplified plan view of a preferred embodiment showing the particular phase relationship between the rotation of the eccentric axis on each of the planetary gears.

The orientation of the eccentricity on each gear with respect to the centre of the gear is indicated by arrows 10A, 10B and 10C. If planetary gear 3A is arbitually selected as the reference gear then it can be seen that its eccentric axis 5A is currently orientated such that the arrow 10A is nominally horizontal. Proceeding in a clockwise direction around the sun gear 2 to gear 3D can be seen that the eccentric axis 5B is arranged such that it is rotated by $2\pi/3$ radians in a counter clockwise direction with respect to the eccentricity on gear 3A. Exactly the same relationship is true between gear 3C and 3B and between gear 3A and 3C.

If this relationship is maintained then the variable component of the resulting moments from each of the platens will cancel each other out, ensuring that there is no torsional vibration transmitted to the user. This is true for any number of gears greater than or equal to three.